

Effect of climate change on agricultural productivity: A case study of Nigeria

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ABSTRACT

Over the time, the escalating buildup of greenhouse gases in the atmosphere has been altering the distribution of precipitation, elevating temperatures, stimulating more frequent instances of severe weather events, and causing shifts in the timing of growing seasons. However, in the Nigerian context, it is worth noting that the agricultural sector, along with its agro-allied industries, holds significant potential to stimulate economic growth and foster diversification away from reliance on crude oil. Against this backdrop, this study examined the impact of climate change on agricultural productivity in Nigeria. The study reveals that climate change variables have a positive impact on agricultural productivity in the country. Based on the findings of the analysis, the efficacy of managing the ongoing fluctuations in climatic variables can be modestly enhanced through the implementation of government policies that prioritize mitigation measures.

Contribution/Originality: The motivation for embarking on this study with reference to Nigeria lies in the fact that little or no empirical studies are currently available in the literature to establish the direction and the magnitude of the impact of climate change on agricultural productivity in the country.

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1. INTRODUCTION

The scientific literature increasingly converges on the notion that the global climate is poised to experience elevated temperatures and altered precipitation patterns in the forthcoming decades. The anticipated consequences of this phenomenon tend to result in sub-optimal or inadequate agricultural output. The available empirical data indicate that climate change has already had discernible outcomes on the productive capacity of the agricultural sector in many countries (Deressa, Hassen, Alemu, Yesuf, & Ringler, 2008; Intergovernmental Panel on Climate Change (IPCC), 2007). This assumption is particularly true for low-income nations, where agricultural productivity is determined by climate and flexible capabilities (Apata, Samuel, & Adeola, 2009; Spore, 2008).

Several African nations, such as Nigeria, heavily rely on weather-dependent agricultural systems for their economic activities. Consequently, these countries are especially vulnerable to the effects of climate change (Dinar, Hassan, Kurukulasuriya, Benhin, & Mendelsohn, 2006). The vulnerability in question has been exemplified by the profound repercussions stemming from the recent floods in the Niger Delta area, as well as the protracted droughts presently observed in some areas of the Northern region. Therefore, in the context of economically disadvantaged nations such as Nigeria, which face significant susceptibility to the ramifications of environmental instability due to

climate change disruptions, it becomes essential to comprehend the adaptive actions undertaken by farmers in response to climatic fluctuations. This comprehension is vital as it facilitates the development of suitable coping mechanisms and strategies.

The extant body of literature and previous empirical investigations have provided substantiation that the contemporary phenomenon of global warming has exerted a discernible impact on the agricultural sector's productivity, thereby engendering a downward trajectory in agricultural output (International Institute for Sustainable Development, 2007; Kurukulasuriya & Mendelsohn, 2006; Lobell et al., 2008). To address the escalating demands for both food and non-food items resulting from population growth, humanity has increasingly relied upon the depletion of arable land, prehistoric water reserves, varied ecosystems, and various other finite assets to satisfy its requirements (Abrahamson, 1989). The phenomenon of resource depletion can be observed in conjunction with various other anthropogenic factors that exert pressure on the environment. The infusion of greenhouse gases into the atmosphere is arguably one of the most significant human impacts. The empirical evidence regarding the ramifications of climate change impact on agricultural productivity has become increasingly apparent, as demonstrated by the work of Spore (2008). A considerable corpus of scholarly investigation has extensively recorded far-reaching implications on various dimensions of human societies, as evidenced by the work of Apata et al. (2009).

Based on the estimations provided by the Intergovernmental Panel on Climate Change (IPCC) (2007), it is anticipated that climate change could pose a more significant challenge to fulfilling global food requirements compared to other limitations faced by agricultural systems in the next five decades or thereabouts. Regarding the impacts of climate change on food security, hunger, and nutritional sufficiency, it will have significant repercussions on population, income, and economic growth. Given that environmental changes like climate change pose a harmful influence on agricultural productivity, it is plausible to anticipate that the repercussions on human well-being would be notably more severe within a socioeconomically disadvantaged global context. In the study conducted by Wolfe et al. (2005), concerns were raised regarding the anticipated surge in food demand in the coming century.

This surge is expected to be driven by population expansion and the growth of real income. Consequently, the study suggests that such an increase in demand may result in a global scarcity of food, exacerbating the already existing issues concerning hunger and undernourishment, especially in developing regions. In the present era, there has been a noticeable escalation in global tensions and apprehensions regarding the impacts of climate change on both the environment and the agricultural sector in Nigeria (Apata et al., 2009; Building Nigeria's Response to Climate Change (BNRCC), 2008). Additionally, farming and food distribution networks may experience heightened strain due to shifting temperatures and precipitation patterns, particularly in cases where these changes occur rapidly and without adequate planning (Building Nigeria's Response to Climate Change (BNRCC), 2008).

Climate change and the inadequacy of mitigation and adaptation efforts pose significant risks to the global economy, second only to the impact of the COVID-19 pandemic (World Economic Forum, 2020). Based on accessible information, it is evident that the previous decade has witnessed the highest recorded temperatures, with the year 2016 standing out as the warmest within this time frame (National Aeronautics and Space Administration (NASA), 2020). Moreover, the empirical evidence suggests that starting from the latter half of the 19th century, there has been a discernible upward trend in the average temperature of the Earth's surface, with a notable rise of more than 1.62°Fahrenheit (0°C).

As a result, the escalating buildup of greenhouse gases in the atmosphere is altering the distribution of precipitation, elevating temperatures, stimulating more frequent instances of severe weather events, and causing shifts in the timing of growing seasons (Egbetokun et al., 2020; Intergovernmental Panel on Climate Change (IPCC), 2007; Ministry of Forestry and Agriculture (MFA), 2010). In the Nigerian context, it is worth noting that the agricultural sector, along with its agro-allied industries, holds significant potential to stimulate economic growth and foster diversification away from reliance on crude oil (Gershon & Patricia, 2019). Nevertheless, the climate-driven nature of this phenomenon is predominantly contingent upon the interplay between precipitation patterns and temperature fluctuations.

According to Ngigi (2009), environmental changes can be understood as modifications in the Earth's climate system resulting from human activities. This alteration, whether direct or indirect, impacts the structure of the atmosphere and ultimately contributes to the phenomenon of climate change. The viability of agriculture depends on climatic conditions, as the two are intricately linked in a global context, as documented by Adejuwon (2006). Nigeria is currently experiencing unfavorable climatic circumstances that are exerting detrimental effects on the well-being of a substantial portion of its population. The volatility of climate patterns poses a significant risk to Nigeria's agricultural sector, thereby affecting productivity levels. In Nigeria, the agricultural sector features a diverse array of food crops, the cultivation of which depends on the availability of rainfall. Consequently, regions with abundant rainfall engage in the cultivation of rain-fed crops, while arid areas of the country opt for crops with lower water requirements.

The growth season of a nation which depends significantly on rain-fed agriculture has been disturbed by floods, droughts, erosion, and off-season rainfall. In some regions, the amount of water flowing through rivers and lakes has decreased with respect to the impacts of environmental changes and climate variability. This has reduced the amount of water available for use in agriculture, which exerts an adverse impact on crop yields (Ozor, 2009). The farming industry in Nigeria has a significant part in the country's GDP, contributing a specific proportion to the overall GDP. Due to the effects of climate variability and environmental changes on farming, the agricultural sector's share of Nigeria's GDP has been shrinking in recent years. All sectors of the agricultural industry are vulnerable to the potential effects of climate change on agricultural productivity. Odekunle (2004) claims that the sector has a sizable effect on the Nigerian economy.

Furthermore, the recurrent volatilities in precipitation and temperature trends have disrupted the benchmark of the rainy season from April to October and the Harmattan season from October to March. From an economic perspective, it is important to consider the potential risks posed by unpredictable rainfall patterns and extreme climatic conditions affecting agricultural productivity (Gershon & Patricia, 2019). In contrast, an abundance of precipitation does have the capacity to stimulate the proliferation of numerous insects and illnesses, thereby exerting detrimental effects on agricultural productivity and livestock reproduction. Rising temperatures facilitate a favourable environment for the proliferation of pests, thereby inflicting harm upon agricultural produce. Furthermore, the emergence and dissemination of the coronavirus disease, commonly referred to as COVID-19, have demonstrated the inherent vulnerability of Nigeria's heavy dependence on crude oil as its primary revenue stream.

This study aims to examine the effect of climate change on agricultural productivity within the context of Nigeria. Previous research on the correlation between climate change and food production, as explored in studies like Deressa et al. (2008), *Building Nigeria's Response to Climate Change* (BNRCC) (2008), and Apata et al. (2009), has not sufficiently yielded valuable insights regarding effective adaptation strategies for the future. However, the findings from these studies have laid the foundation for the current study.

2. LITERATURE REVIEW

2.1. Climate Change Trends in Nigeria

From Figure 1, the northern part of Nigeria experiences annual thermal level fluctuations ranging from 12°C to 45°C, whereas in the southern region, the thermal level varies between 17°C and 37°C. The nation's average thermal level has exhibited a consistent upward trend over the course of the 20th and 21st centuries. From 1901 to 2016, there was a gradual increase of 0.03°C per decade. However, in the more recent past, specifically over the last 30 years, the rate of thermal level increase has accelerated to 0.19°C per decade. In Nigeria, the dry season is characterized by the highest thermal levels, which remain consistent across the country from the coastal regions to the interior. According to GERICS (2015), there has been a significant reduction in the surface area of Lake Chad, which has decreased from approximately 40,000 km² to 1,300 km². This decline can be attributed to the escalating temperatures experienced over the past four decades, leading to the expansion of the Sahara Desert. The phenomenon under discussion has predominantly manifested itself within the agricultural sector of Nigeria.

Based on the prevailing climate change patterns in Nigeria, it is expected that there will be a notable rise in the occurrence and intensity of flooding events due to amplified precipitation levels. Based on the projected data, it is expected that the eastern and central regions will encounter a rise in aridity and drought conditions, thereby potentially impacting the local population's livelihoods and means of sustenance. Droughts have had profound implications on various socio-economic aspects, including food security, population dynamics, geopolitical tensions, and ecological diversity. The central and eastern regions are anticipated to encounter agricultural challenges due to prolonged periods of seasonal droughts. In 2012, Nigeria experienced a significant and catastrophic flooding event, which had profound implications for the country's agricultural sector. In the year 2012, a significant inundation event had a profound impact on a substantial population of approximately seven million individuals, resulting in substantial economic losses amounting to an estimated five hundred million dollars. The inundation event that occurred in the year 2015 led to the unfortunate displacement of a significant population of approximately one million individuals. Furthermore, this calamity incurred a substantial financial burden, amounting to a staggering \$25 million, as reported by the FAO (2019).

Based on a comprehensive study conducted by the DFID (2009), it has been projected that Nigeria may potentially experience a decline in its Gross Domestic Product (GDP) ranging from 2% to 11% by the year 2020 if appropriate adaptation measures are not implemented. Based on the findings of the Post-Disaster Need Assessment (PDNA) Report, the flood incident that transpired in 2012 resulted in substantial economic repercussions, amounting to a staggering \$16.9 billion in damages. This financial toll is significant, as it corresponds to a notable 1.4% reduction in real GDP growth. The interplay between fluctuations in rainfall trends, which are impacted by the escalating temperatures, as well as the presence of severe weather events like floods and droughts, will inevitably exert profound effects on both the stability of agricultural output and the accessibility of water supply. Moreover, it is important to acknowledge that abundant rainfall can lead to crop waterlogging and soil erosion, thereby diminishing agricultural productivity and exacerbating vulnerability to food insecurity. Based on current projections, it is anticipated that Nigeria and the broader West African region may encounter food insecurity because of the effects of environmental changes and climate change variability. The prospective consequences encompass financial setbacks, infrastructure impairment, and even human casualties.

Regular occurrences of flooding have a significant impact on land deterioration and soil erosion, posing considerable challenges to agricultural productivity and the financial well-being of rural communities. The prospective influence of elevated temperatures and reduced water availability on agriculture could pose a substantial threat to food security. According to the 2018 report published by the United States Agency for International Development (USAID), despite continuous humanitarian aid, diligent policy efforts, and active government involvement in the agricultural sector, the state of food security and nutrition in northeastern Nigeria remains tenuous. Individuals who have experienced internal displacement within the country and are currently residing in camps or camp-like environments exhibit the most significant inadequacy in terms of unfulfilled nutritional requirements. Vulnerable households often face constraints regarding land and cattle availability, hindering their ability to produce sufficient food for their sustenance. The prevailing circumstances in rural areas have led to deficiencies in the nutritional needs of the population, primarily due to the exacerbation of violence and the concomitant insufficiency of healthcare infrastructure and food supplies within the country. The Food and Agriculture Organization (FAO) released a report in 2019.

Temperature change in the last 50 years

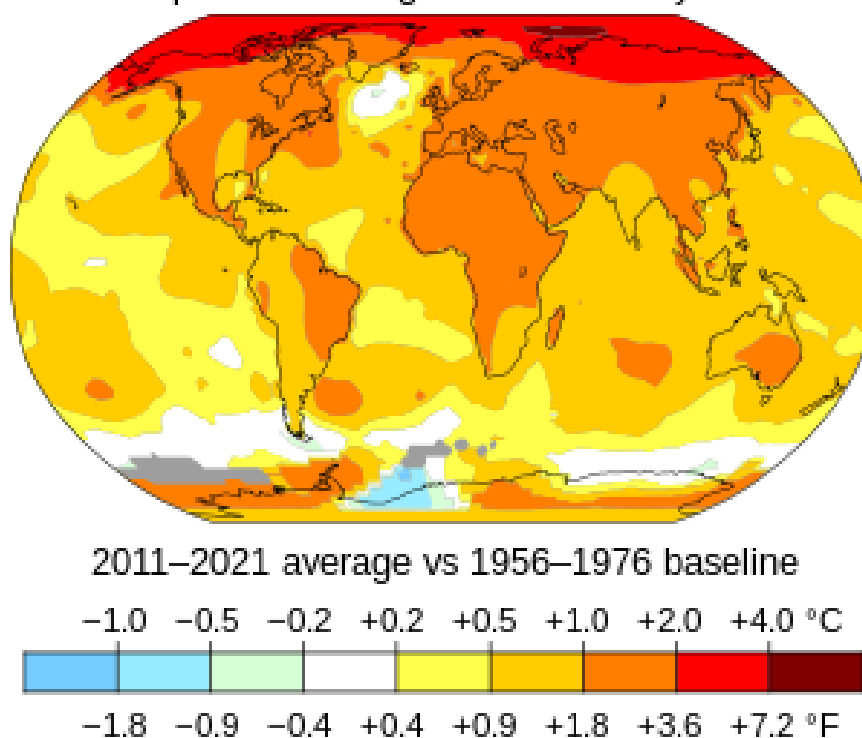


Figure 1. Temperature change in the last 50 years in Nigeria.

Source: Wikipedia.

2.2. Empirical Review

Recent empirical research has substantiated the notion that alterations in climate patterns and fluctuations possess the potential to exert significant influences on agricultural production (Skoufias, Rabassa, Olivieri, & Brahmabhatt, 2011).

Table 1 is a summary of different study papers that look at how climate change affects the productivity of agriculture in Nigeria. Each study examined the link between climate change variables and agricultural productivity using different methods and approaches to data analysis. These studies provide valuable insights into the complex relationship between climate change and Nigeria's food production capacity. They highlight the importance of considering various climate change variables and technological factors when developing strategies to mitigate the impacts of climate change on agriculture.

Table 1. Empirical review of previous studies on climate change and agricultural productivity in Nigeria.

Name of Author	Title of Paper	Findings
Adedeji, Tiku, Waziri-Ugwu, and Sanusi (2017)	The impact of climate change on rice production in Adamawa State, Nigeria.	The study used regression analysis techniques to analyze the impact of climate change on rice production. Based on the findings, rainfall had a positive and statistically significant impact on rice yield, while temperature was found to have a negative impact.
Ayinde, Muchie, and Olatunji (2011)	Agricultural output and climatic change in Nigeria: a co-integration model analysis.	The study utilized a co-integration approach as a model for analysis. The study found that rainfall and temperature have both positive and negative effects, respectively, on agricultural output, as determined by descriptive statistics and the co-integration method.
Agba, Adewara, Adama, Adzer, and Atoyebi (2017)	An investigation of the impact of climate change on agricultural production in Nigeria.	According to the findings of the study, which made use of time series data, the results revealed that rainfall has both short-run and long-run relationships with crop production. Meanwhile, temperature and carbon dioxide emissions indicate a negative and significant effect on crop production in the long run.

Name of Author	Title of Paper	Findings
Aondoakaa (2012)	Changes in temperature and how they affect farming in Nigeria's Federal Capital Territory (FCT), Abuja.	The findings from the study showed that there is a positive relationship between temperature, rainfall, and crop output in Abuja over a period of 10 years. The study used a method called correlation and regression analysis. Land and watering systems should also be part of the plan.
Exenberger, Pondorfer, and Maik (2014)	Estimating the Impact of Climate Change on Agricultural Production: Accounting for Technology Heterogeneity Across Countries PDF Logo. Germany.	The study's findings indicate that middle- and low-income countries experience the impacts of rising temperatures, alterations in precipitation patterns, and increased frequency of droughts. These detrimental effects are particularly pronounced in the Sub-Saharan Africa region. The findings additionally indicate that variations in technology across countries contribute to disparities in the impact of climate change on agricultural production.
Ekpenyong and Ogbuagu (2015)	An econometric analysis of the relationship between climate change and agricultural productivity in Nigeria.	The results of the study show that increased carbon emissions have a significant effect on the productivity of agriculture over a long period of time.
Ejemeyovwi, Obindah, and Doyah (2018)	Finding a sustainable balance between CO ₂ emissions and crop yield.	The research utilized the Fully Modified OLS method to investigate the relationship between crop production and CO ₂ emissions. The results indicate a statistically significant and positive long-term association between these variables. The findings presented in this study diverge from those of previous research, as they reveal a positive, long-term impact of CO ₂ emissions on crop production, contrary to the commonly held belief of its inherent negativity. This stands in opposition to prevailing hypotheses that suggest an adverse relationship between elevated carbon dioxide (CO ₂) levels in a tropical nation, such as Nigeria, and the productivity of agricultural crops.

3. METHODOLOGY

Nigeria is the focus of the investigation. Located in western sub-Saharan Africa, Nigeria is bounded by the Republic of Benin to the west, the Republics of Chad and Cameroon to the east, and the Republic of Niger to the north. The Gulf of Guinea is also Nigeria's coastline (Wikipedia, 2009). In the context of Nigeria, the classification of climate regions suggests the presence of three distinct areas: the southernmost region, the northernmost region, and the remaining portion of the country. The southernmost region is characterized by a tropical rainforest climate, exhibiting an annual precipitation range of 60 to 80 inches. The region commonly referred to as the far north is characterized by a climate that closely resembles that of a desert, exhibiting an annual precipitation level of less than 20 inches. The remaining regions of the country, spanning from the northernmost to the southernmost points, are characterized by savannah landscapes and experience an annual precipitation ranging from 20 to 60 inches (NationMaster, 2009).

3.1. Theoretical Framework and Model Specification

3.1.1. Theoretical Framework

The empirical framework for the study follows the derivation in Bond et al. (2007). Although the derivation of this framework was used for panel studies, its theoretical explanation can also be applied to time series studies, as it best fits in explaining the dynamic linkages between climate variables and agricultural crop production, as shown below in Equation 1.

$$Y_t = \phi^T A_t L_t \quad (1)$$

$$\frac{\Delta A_t}{A_t} = g + \gamma T \quad (2)$$

Where Y is aggregate output, L measures population, A measures labor productivity, and T measures climate. Equation 1 captures the level of effect of climate on production; that is, the effect of current temperature or precipitation on crop yields. Equation 2 captures the growth effect of climate; i.e., the effect of climate on features such as institutions that influence productivity growth. Taking logs in the production function and differencing with respect to time, we have the dynamic growth equation:

$$g = g + (\beta + \gamma)T_t - \beta T_{t-1} \quad (3)$$

Where gt is the growth rate of per-capita output. The “level effects” of climate shocks on output, which come from Equation 1, appear through β . The “growth effects” of climate shocks, which come from Equation 2, appear through γ . The growth Equation 3 allows separate identification of level effects and growth effects through the examination of transitory weather shocks. In particular, both effects influence the growth rate in the initial period of the shock. The difference is that the level effect eventually reverses itself as the climate returns to its prior state. For example, a temperature shock may reduce agricultural yields, but once the temperature returns to its average value, agricultural yields bounce back. By contrast, the growth effect appears during the climate shock and is not reversed: a failure to innovate in one period leaves the country permanently further behind. The growth effect is identified in (3) as the summation of the climate effects over time. The above reasoning extends to models where climate effects play out more slowly. With more general lag structures in (1) and (2), the growth effect is still identified by summing the lagged effects of the climate shock.

3.1.2. Model Specification

In addition to the above theoretical framework, this study adapted models from these studies, Afolayan and Aderemi (2019) and Obiakor, Omoyele, Olanipekun, and Aderemi (2021), in which its mathematical equation is given as follows;

$$AVA = F(CO2EMS, CRP) \quad (4)$$

In improving the robustness of model 1, some control variables such as access to electricity, internet, and trade openness were added to the model because these variables have both direct and indirect influences on agricultural productivity in Nigeria (Enilolobo, Babalola, Nnoli, Ajibola, & Okere, 2022). Thus, the model (4) is expanded econometrically as follows;

$$AVA = \beta_0 + \beta_1 CO2EMS + \beta_2 CRP + \beta_3 ATE + \beta_4 ATI + \beta_5 TOP + \mu \quad (5)$$

Where;

AVA = Agricultural value added as a percentage of GDP, measured in percentage.

CO2EMS=Carbon Emissions.

CRP = Change in rainfall patterns. This is measured by the average annual precipitation in millimeters.

ATE=Access to electricity as a percentage of the population.

ATI=Access to the internet as a percentage of the population.

TOP=Trade Openness. Consequently, the detailed description of the utilized variables is contained in the Table 2.

Table 2. Description of variables for the effect of climate change and agricultural productivity in Nigeria.

Variable	Description	A priori expectation
CO2 emissions	CO2 emissions are the release of carbon dioxide (CO2) into the atmosphere. Carbon dioxide, as a greenhouse gas, has a significant impact on the Earth's climate system. Anthropogenic activity, such as the combustion of fossil fuels (coal, oil, and natural gas) for energy generation, deforestation, and industrial operations, are the primary contributors to CO2 emissions.	Negative
Change in rainfall patterns	Change in rainfall patterns refers to shifts in the distribution, intensity, and timing of precipitation over a particular area or region. These changes can manifest in various ways, such as alterations in the frequency and duration of rainfall events, the occurrence of extreme weather events like heavy downpours or prolonged droughts, and variations in the seasonal distribution of rainfall.	Positive
Access to electricity	Access to electricity refers to the availability and ability of individuals, households, communities, and businesses to connect to and use electrical power from the grid or other sources for various purposes. It is a critical indicator of a country's or region's level of development and the well-being of its population.	Positive
Access to internet	Access to the internet refers to the ability of individuals, communities, and organizations to connect to and use the global computer network known as the internet. It enables users to access a vast array of digital information, communicate with others, and utilize various online services and platforms.	Positive
Trade openness	Trade openness, also known as economic openness or international trade openness, refers to the extent to which a country or an economy participates in international trade and engages with the global economy. It is a measure of how open a country's markets are to foreign trade, including imports and exports of goods and services.	Positive
Agricultural value added	Agricultural value-added is a key economic indicator that measures the contribution of the agricultural sector to the overall economy of a country or region. It represents the difference between the total value of agricultural outputs (crops, livestock, forestry, fisheries, etc.) produced by the agricultural sector and the total value of intermediate inputs (such as seeds, fertilizers, machinery, and other materials) used in the production process.	Dependent variable

Table 4 provides an explanation of the variables used in the empirical study of the impact of climate change on agricultural productivity in Nigeria include CO₂ emissions, change in rainfall patterns, agricultural value added, electricity access, and internet access. CO₂ emissions measure the amount of carbon dioxide released into the Earth's atmosphere as a result of anthropogenic activities such as the combustion of fossil fuels and industrial operations. These emissions have a considerable impact on changing climatic patterns and exacerbating global warming. Change in rainfall patterns refers to alterations in the distribution, intensity, and timing of precipitation, which can result in meteorological phenomena such as droughts, heavy precipitation events, and altered seasonal rainfall patterns. These changes significantly impact ecosystems and agricultural activities. Agricultural value added is a critical indicator for assessing the economic contribution of the country's agricultural sector. It encompasses the comprehensive value of agricultural outputs and intermediate inputs, providing valuable insights into the sector's productivity and overall progress. The metric of electricity access measures the extent to which electrical power is accessible and utilized within residential, communal, and commercial settings. This metric is vital for fostering economic and social progress, as well as enhancing overall welfare. The concept of internet access involves analyzing the capacity of individuals and entities to establish and employ internet connections, thereby facilitating access to information, communication, education, and economic opportunities.

3.1.3. Data Sources and Scope of the Study

In investigating the relationship between climate change and agricultural productivity in Nigeria using secondary data, this study utilized annual time series data from 1990 to 2020. All data were collected from the World Development Indicators (WDI).

4. RESULT AND DISCUSSION

The results of this study are presented in the following order: descriptive statistics and graphical trends.

4.1. Descriptive Statistics

Descriptive statistics are numerical measurements that summarize and describe the main characteristics of a dataset. They provide valuable insights into the performances of the study's variables.

Table 3. Descriptive statistics for the effect of climate change on agricultural productivity in Nigeria.

Variables	CO ₂ EMS	CRP (MM per year)	AVA (%)	ATE (%)	ATI (%)	TOP (%)
Mean	10.7	27.3	24.3	46.8	9.55	36.5
Median	10.6	27.3	24.1	47.5	3.55	37.0
Maximum	19.7	27.8	36.9	59.3	35.5	53.2
Minimum	4.24	26.5	19.9	27.3	0.00	16.3
Std. Dev.	3.84	0.29	3.82	7.81	11.8	9.21
Skewness	0.43	-0.34	1.52	-0.46	0.92	-0.20
Kurtosis	2.86	2.85	5.73	2.49	2.43	2.62
Jarque-Bera	1.02	0.62	21.6	1.46	4.88	0.40
Probability	0.60	0.73	0.00	0.48	0.08	0.81
Sum	334	819	754	145	296	113
Sum Sq. Dev.	442	2.55	439	183	424	254
Observations	31	31	31	31	31	31

Table 3 reveals the result of the summary statistics for the study provides valuable insights into the central tendency, measures of dispersion, and the shape of the dataset, allowing for a better understanding of the variability and characteristics of the variables under consideration. The table presents information about the effect of climate change on agricultural productivity in Nigeria using six variables over the period of analysis. The mean value for Co₂EMS (Carbon emission) in Nigeria is 10.7%, with maximum and minimum values of 19.7% and 4.2%, respectively. This indicates that carbon emission in Nigeria over the last 30 years has been relatively low, thus having a limited impact on the agricultural sector. The reason for this might be that the adoption of sustainable farming techniques, such as agroforestry, organic farming, and reduced tillage, which sequester carbon in the soil and reduce greenhouse gas emissions associated with conventional farming, has not been widely deployed. Moreover, the mean is greater than the standard deviation, implying that the data is moderately dispersed from its mean value. Additionally, the skewness is positive, and the kurtosis is platykurtic because it is less than 3.

In the same vein, the mean for CRP (Change in rainfall pattern) is 27.3%, while the minimum and maximum values are 26.5% and 27.8%, respectively. The mean value and the minimum and maximum values for CRP are below average, which implies that the patterns of rainfall have been relatively low, potentially leading to water scarcity due to erratic rainfall patterns. This could affect the productivity of the agricultural sector, thereby having a multiplying effect on food production and food security. Additionally, the mean value for CRP is greater than the standard deviation, indicating that the data is moderately dispersed. The skewness value is negative, and the kurtosis value is platykurtic.

However, the mean value for AVA (agricultural value added) is 24.3%, and the maximum and minimum values are 36.9% and 19.9%, respectively. This suggests that agricultural productivity in Nigeria over the period of the analysis has been very low or below average. Also, the mean value is greater than the standard deviation, which indicates that

the data is moderately dispersed around its mean. Furthermore, the mean value for ATE (access to electricity) is 46.8%, while the maximum and minimum values are 59.3% and 27.3%, respectively. The mean value for ATE is below average, but the percentage shows that almost half of the population has access to electricity over the period of the analysis. A possible reason for this might be that the government has not been investing adequately in electricity during this period, although the data is moderately dispersed around its mean. Additionally, the mean value for ATI (access to internet) is very low over the period of the analysis. This implies that many people have not gained access to the internet, especially in rural areas. A possible reason for this might be a lack of information, knowledge, and the inability to utilize the internet effectively.

Lastly, the mean value for TOP (trade openness) is 36.5% with a maximum of 53.2% and a minimum of 16.3%, which indicates a low exporting capacity from the agricultural sector in international trade because trade openness often relies on a country's ability to export goods and services. This might be due to the effect of changes in rainfall patterns, which could be affecting the reduction of the agricultural sector's productivity, thereby limiting the country's export capacity in international trade.

4.2. Trend Analysis

Trend analysis is a statistical technique used to identify and understand patterns or trends in data over time. It involves analyzing data points collected at regular intervals to discern any consistent upward, downward, or stable movements in the data series. Trend analysis is valuable for decision-making and strategic planning, as it can provide insights into long-term patterns, detect emerging trends, and identify potential opportunities or risks.

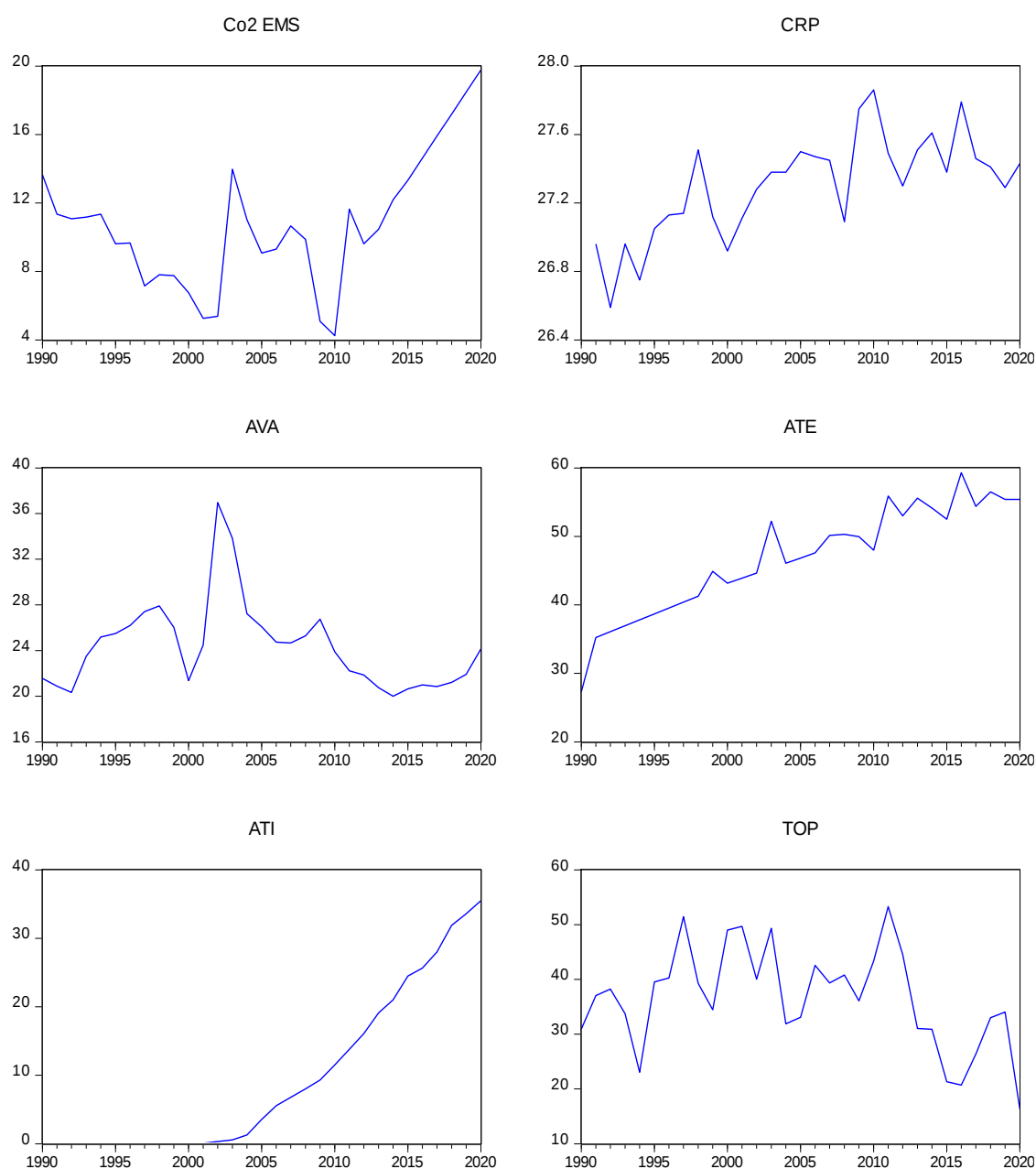


Figure 2. Trend analysis of the study's variables.

Figure 2 presents a graphical representation of the level and rate at which climate change has affected agricultural productivity over the past 30 years, using six variables as indicators and parameters for the analysis. The variables used are Co2EMS (carbon emissions), CRP (change in rainfall pattern), AVA (agricultural value added), ATE (access to electricity), ATI (access to internet), and TOP (trade openness). Based on the graphical analysis above, Co2EMS (carbon emissions) has shown an irregular pattern; from 1990-2000, there was a decline, but from 2000-2010, there was a period of decline followed by an increase, which continued all the way to 2020.

The trend for CRP (change in rainfall pattern) has been irregular and erratic over the period of the analysis, as seen from the graph above. The pattern has just been fluctuating, which suggests that the patterns of rainfall are relatively unstable.

Furthermore, the trend for AVA (agricultural value added) over the period of the analysis suggests that the pattern has been going upward and downward, but from 2000-2010, AVA showed a sharp increase. In the same vein, the trend for ATE (access to electricity) exhibits an upward increase over the period of the analysis, which suggests that there has been substantial access to electricity over time. Additionally, for ATI (access to internet), the trend analysis showed that from 1990-2000, there was little or no access to the internet at all; however, between 2000-2005, the trend indicated that people started having access to the internet, and it continued with an upward increase over the period of the analysis. Meanwhile, TOP (trade openness) has also shown a fluctuating upward and downward movement, indicating the instability of agricultural productivity.

Table 4. Unit root test on the effect of climate change on agricultural productivity in Nigeria.

Variable	Augmented Dickey Fuller				Order of variable
	Level	Probability	1 st Difference	Probability	
CO2EMS	-2.96	0.62	-3.69	0.00	I(1)
CRP	-2.62	0.42	-3.67	0.00	I(1)
AVA	-2.62	0.23	-3.69	0.00	I(1)
ATE	-3.67	0.04	-3.67	0.00	I(0)
ATI	-1.61	0.99	-2.64	0.00	I(1)
TOP	-2.96	0.08	-2.97	0.00	I(1)

4.3. Stationarity Test

Table 6 presents the results of the stationarity test, also known as the unit root test. Six variables were used to conduct the analysis, which are CO2EMS, CRP, AVA, ATE, ATI, and TOP. Out of these variables, five became stationary after the first difference, while ATE was stationary at level. Since most of the variables follow an order one [I(1)] process, the next step is to test if there exists a long-run relationship (cointegration) among the variables.

Table 5. Cointegration test results for the effect of climate change on agricultural productivity.

Unrestricted cointegration rank test (Trace)				Prob.
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	
None	0.88	154	95.7	0.00
At most 1	0.812	93.7	69.8	0.00
At most 2	0.56	46.9	47.8	0.06
At most 3	0.34	23.4	29.7	0.22
At most 4	0.22	11.5	15.4	0.18
At most 5	0.14	4.33	3.84	0.03

4.4. Johansen Cointegration Test

The results of the trace statistics in Table 5 indicate that the hypothesis of no cointegration among the variables can be rejected. The results revealed that at least three cointegrating vectors exist among the variables of interest. Considering the existence of a long-run relationship established among the variables as shown in Table 5, the analysis employed the dynamic ordinary least squares regression estimation technique in order to ascertain the effect of climate change on agricultural productivity.

Table 6. Correlation analysis.

Variables	AVA	CO2_EMS	CRP	ATE	ATI	LTOP
AVA	1.00					
CO2_EMS	-0.36	1.00				
CRP	0.02	0.05	1.00			
ATE	-0.22	-0.49	0.715	1.00		
ATI	-0.49	0.72	0.49	0.62	1.00	
TOP	0.30	-0.57	-0.15	-0.26	-0.54	1.00

4.5. Correlation Matrix

The correlation analysis findings presented in Table 6 indicate the absence of substantial evidence supporting the existence of significant multicollinearity among the variables. This phenomenon can be attributed to the observation that the correlation coefficient between the variables in the table is not above 0.8. Therefore, the explanatory variables are free from the problem of multicollinearity.

Table 7. Dynamic Ordinary Least Squares Regression for the Effect of Climate Change on Agricultural Productivity in Nigeria.

Variables	Coefficient	Std. Error	t-Statistic	Prob.
CO2_EMS	1.47	0.38	3.83	0.00
CRP	4.14	8.91	0.46	0.65
ATE	0.48	0.47	1.02	0.34
ATI	-0.35	0.16	2.08	0.08
TOP	0.41	0.19	2.11	0.07
C	-136.	223	0.61	0.56
R-squared	0.90			
Dependent variable: Agricultural productivity				

Table 7 presents the outcome of the dynamic ordinary least squares analysis of the nexus between climate change and agricultural productivity in Nigeria. The coefficient values for each variable (CO2EMS, CRP, AVA, ATE, ATI, TOP) are provided, accompanied by their respective t-statistics and associated probabilities. The obtained outcome reveals an R-squared value of 0.907020, indicating that over 90% of the overall variability observed in the dependent variable was accounted for by the independent variables incorporated within the model, namely CO2EMS, CRP, AVA, ATE, ATI, TOP, and C. This suggests that the econometric model exhibits a favorable level of goodness-of-fit, indicating a strong relationship between the independent variables and the dependent variable.

With respect to the result from the model, it therefore implies that the independent variables, which are carbon emission and change in rainfall patterns, thus have a positive impact on the dependent variable (AVA), such that a unit increase in carbon emission and change in rainfall pattern will lead to a 1.478748% and 4.140856% increase in agricultural productivity, AVA, respectively. Furthermore, the control variables, which are ATE (Access to electricity) and TOP (Trade openness), portrayed a positive impact on agricultural productivity. Whereas, ATI (Access to internet) exhibited a negative impact on agricultural productivity.

5. CONCLUSION AND POLICY RECOMMENDATION

The analysis examines the relationship between climate change and agricultural productivity in Nigeria. The empirical examination of agricultural productivity reveals a pattern of oscillating productivity within the sector. The observed fluctuations in precipitation patterns have demonstrated a degree of variability, analogous to the fluctuations observed in carbon emissions. Based on the findings of the analysis, the efficacy of managing the ongoing fluctuations in climatic variables can be modestly enhanced through the implementation of government policies that prioritize mitigation measures. Additionally, the private sector can play a crucial role by directing their efforts towards augmenting agricultural output via technological advancements, thereby avoiding any adverse impact on climate dynamics while simultaneously bolstering production levels. For the purpose of enhancing and maintaining agricultural production, it is advisable to employ irrigation as a reliable means of water supply. This mode of water provision is deemed most appropriate, as it is expected to yield favorable environmental outcomes. Therefore, it is imperative that efforts and policies are directed towards the provision of efficient irrigation infrastructure. Consequently, based on the empirical findings derived from this study, it is advisable for businesses, policymakers, and government agencies to contemplate the following recommendations:

- Implementing environmental sustainability and climate change mitigation strategies to lessen their carbon footprint and cut greenhouse gas emissions. According to a trend analysis of carbon dioxide emissions, these emissions have significantly grown since 2010. Taxing carbon emissions, encouraging the use of renewable energy sources, supporting sustainable agricultural practices by reducing the use of inorganic fertilizers, as well as boosting afforestation and the use of organic manure, are some of the strategies that can be used.
- Adaptation: This pertains to necessary and required steps taken to make Nigerian agriculture more resilient to climate change. Farmers who cultivate resilient crops and animals, along with incentive programmes that fund the study and development of new methods to boost crop yields (such as biotechnology), are among these initiatives. Businesses in the agriculture sector are encouraged to collaborate with energy companies (and/or the government) to implement integrated hydropower and irrigation projects in drought-prone areas. To help farmers and agro-allied businesses recover from the COVID-19 closures, the government should increase spending on agriculture (both capital and recurring). This has the potential to enhance mechanized farming with high-tech tools and climate-resilient seedlings, which would be beneficial for both agricultural and livestock production.
- National education campaigns to inform farmers and herders of upcoming changes in climatic extremes.

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